The author considers what he has found as the weakest part of a dome to be the position in which an iron belt must be placed to produce the greatest effect in counteracting the thrust of the dome. If this be done, the thickness of the pier may be considerably diminished, and need not greatly exceed the strength necessary for supporting the superincumbent weight acting vertically downwards.

III. "A Supplementary Memoir on Caustics." By A. Cayley, F.R.S. Received November 15, 1866.

(Abstract.)

It is near the conclusion of my "Memoir on Caustics," Phil. Trans. vol. cxlvii. (1857), pp. 273, 312, remarked that for the case of parallel rays refracted at a circle, the ordinary construction for the secondary caustic cannot be made use of (the entire curve would in fact pass off to an infinite distance), and that the simplest course is to measure off the distance GQ from a line through the centre of the refracting circle perpendicular to the direction of the incident rays. The particular secondary caustic, or orthogonal trajectory of the refracted rays, obtained on the above supposition was shown to be a curve of the order 8; and it was further shown by consideration of the case (wherein the distance GQ is measured off from an arbitrary line perpendicular to the incident rays), that the general secondary caustic or orthogonal trajectory of the refracted rays was a curve of the same order 8. The last-mentioned curve in the case of reflexion, or for $\mu=-1$, degenerates into a curve of the order 6; and I propose in the present supplementary memoir to discuss this sextic curve; viz. the sextic curve which is the general secondary caustic or orthogonal trajectory of parallel rays reflected at a circle.

November 30, 1866.

ANNIVERSARY MEETING.

Lieut.-General SABINE, President, in the Chair.

Dr. Gladstone, on the part of the Auditors of the Treasurer's Accounts appointed by the Society, reported that the total receipts during the past year, including a balance of £15 9*s.* carried from the preceding year, amounted to £4295 16*s.* 11*d.*; and that the total expenditure in the same

period amounted to £3629 15*s.* 5*d.*, leaving a balance of £638 8*s.* 1*d.* at the Bankers, and of £27 13*s.* 5*d.* in the hands of the Treasurer.

The thanks of the Society were voted to the Treasurer and Auditors.

The Secretary read the following Lists:—

Fellows deceased since the last Anniversary.

Royal.

His Majesty Leopold, King of the Belgians, K.G.

On the Home List.

Benjamin Guy Babington, M.D.
William Thomas Brande, D.C.L.
Right Hon. Sir James Lewis Knight Bruce, Knt., D.C.L.
Richard John Hely Hutchinson, Earl of Donoughmore.
Sir Charles Locke Eastlake, D.C.L.
Joseph Edye, Esq.
G. W. Featherstonhaugh, Esq.
Charles Lord Glenelg, D.C.L.
William Gravatt, Esq.
John Scandret Harford, D.C.L.
Charles James Hargreave, LL.D.
William Henry Harvey, M.D.
Robert Hunter, Esq.
Percival Norton Johnson, Esq.
Edward Kater, Esq.
John Lee, LL.D.
Rev. Samuel Roffy Maitland, D.D.
Thomas Spring Rice, Lord Monteagle of Brandon.
Francis Thornhill Baring, Baron Northbrook.
Horatio William Walpole, Earl of Orford (in 1858).
George Rennie, Esq.
Henry Darwin Rogers, LL.D.
Edward James Seymour, M.D.
Samuel Reynolds Solly, Esq.
Joseph Toynbee, Esq.
Lieut.-Col. Sir John Maxwell Tylden, Knt.
Rev. William Whewell, D.D.
Right Hon. Sir James Wigram, Knt., M.A.
Nicholas Wood, Esq.

On the Foreign List.

Georg Friedrich Bernhard Riemann.

Change of Name.

Rev. Henry Christmas to Noel-Fearn.

Defaulter.

Colonel John Le Couteur.

Fellows elected since the last Anniversary.

On the Home List.

John Charles Bucknill, M.D.
Rev. Frederic William Farrar.
William Augustus Guy, M.B.
James Hector, M.D.
John William Kaye, Esq.
Hugo Müller, Ph.D.
Charles Murchison, M.D.
William Henry Perkin, Esq.
The Ven. John Henry Pratt, M.A.
Capt. George Henry Richards, R.N.
Thomas Richardson, Esq., M.A.
William Henry Leighton Russell, Esq.
Rev. William Selwyn, D.D.
Rev. Richard Townsend, M.A.
Henry Watts, B.A.

On the Foreign List.

Franz Cornelius Donders.
Georg Friedrich Bernhard Riemann.
Gustav Rose.

Readmitted.

William Bird Herapath, M.D.

The President then addressed the Society as follows:—

Gentlemen,

During the autumnal recess, and in the absence of the President, the Treasurer, on learning that the Government had it in contemplation to assign the main building of Burlington House, now appropriated to the Royal, Chemical, and Linnean Societies, to the Royal Academy (together with ground in its rear for the erection of additional buildings), deemed it advisable in the interests of the Society, and after consultation with the Senior Secretary, to address a letter to the Earl of Derby. The officers of the Society were referred by his Lordship to the Chief Commissioner of Works, by whom they were informed in reply that due provision was to be made for the Societies, and that the Architects, Messrs. Banks and Barry, with whom the Office were to advise on the subject, were instructed to confer with the Council of the Royal Society. Those gentlemen having accordingly communicated to the Council that they are directed to report to the Government on the accommodation that can be provided for the Royal and the other Societies in new buildings, to occupy part of the space between Burlington House and Piccadilly, the Council have appointed a Committee to consider the whole matter and to confer with the Architects thereupon. The Committee have had an interview with Mr. Banks, and have handed in a statement setting forth the nature and extent of accommodation that will be required for the Society in lieu of their present apartments. There, so far as we are informed, the matter rests for the present, but from the tenor of the communications which have passed, there seems every reason to feel confident that the Society will be suitably and amply provided for.

I had the pleasure of announcing at the last Anniversary that the

printing of the Catalogue of Scientific Papers, in the preparation of which we have been so long engaged, was at length commenced. Twenty-eight quarto sheets are now printed and eight more are in type. The work would now have been further advanced, had not the Superintending Commitee in the mean time obtained access to additional Periodical Works, containing Memoirs deserving to be included in the Catalogue, and too numerous to warrant their being postponed for a supplement. The printing has therefore been interrupted for a time in order to allow of the insertion of these additional titles in their proper places. Moreover, proofs of every sheet are supplied to several of the Members of the Library Committee who separately revise them ; and this mode of proceeding no doubt somewhat protracts the work, but it has the more than compensating advantage of securing the greatest attainable accuracy.

The attention of your Council has been much occupied in the past year in complying with a request from Her Majesty's Government for the advice and co-operation of the Royal Society in the re-organization of the Meteorological Department of the Board of Trade, and in preparing the preliminary arrangements for the establishment of a system of British Land-Meteorology to be carried out under the authorization of that Board.

Perhaps there is no branch of scientific research in which a greater amount of human labour has been expended than has been the case in Meteorology,—a natural consequence of its intimate connexion in so many ways with the interests and pursuits of man ; and it may perhaps be said with equal truth that there is no department of natural knowledge in which the labour bestowed has been of a more desultory character, or the value and importance of the conclusions less commensurate with the time and labour bestowed on their acquisition. The object to be desired, therefore, is scarcely so much to give a stronger impulse to the spirit of inquiry, as to aid in giving to that which exists a more systematic direction. This has been attempted in several of the continental States of Europe and America, by the establishment at the expense of the respective governments, and under the superintendence of men eminently qualified by theoretical and practical knowledge, of systematic climatological researches ; and, as regards the individual states themselves, it may be confidently said that the results have been very beneficial.

For some time past it has been desired to establish a closer connexion between these independent and separate systems of observation, by effecting an assimilation of instrumental means, and of the modes and times of observation. It was chiefly in this view that the assemblage took place by special invitation, at the Cambridge Meeting of the British Association in 1845, of the Directors of the principal meteorological (and magnetical) observatories in Europe and America ; and that a second meeting took place at Brussels in 1853. The difficulty that impeded success on these two occasions cannot be better stated than in the words of Captain Maury, in

his Report to the Government of the United States, by whom he had been appointed to visit the principal European Meteorological Observatories for the express purpose of urging a uniformity of procedure.

"I would recommend that the United States should abandon, for the time at least, that part of the 'Universal System' which relates to the Land, and that we should direct our efforts mainly to the Sea, where there is such a rich harvest to be gathered for navigation and commerce. I am inclined to make this recommendation in consequence of the evident reluctance with which Russia, Austria, Bavaria, Belgium, and other powers seem to regard any change in their systems of meteorological observations on shore. Each country seems to have adopted a system of its own, according to which its labourers have been accustomed to work, and to which its meteorologists are more or less partial. Any proposition having in view for these systems a change so radical as to bring them into uniformity, and reduce them to one for all the world would, I have reason to believe, be regarded with more or less jealousy by many,—not so, however, with regard to the sea; that proposal meets with decided favour and warm support."

The most hopeful way of removing the difficulties which impeded the adoption of a system in which all might willingly unite was obviously the introduction of instruments which should be continuously self-recording, and which, after sufficient trial, should receive general approval. The importance of such a substitution had been recognized at the Observatory of the British Association at Kew at a very early date, even before the Cambridge Meeting of the British Association in 1845; and at that meeting the satisfactory performance was announced of a photometrically self-recording barometer, self-compensated also for temperature, devised by Mr. Francis Ronalds, the Honorary Director of the Kew Observatory,—the same to whose merits in regard to the instantaneous transmission of messages by means of electricity, at the very early date of 1823, attention has been recently called in the public journals. Encouraged by this success in one instrument, the Directors of the Kew Observatory proceeded, as rapidly as the means at their disposal enabled them to do, towards the provision of self-recording instruments for the other meteorological elements (as well as for the magnetical elements), and were considerably advanced in their preparations when in 1854 the Board of Trade informed the President and Council that, in fulfilment of a previous earnest recommendation to that effect from the Royal Society, they were "about to submit to Parliament an estimate for an office for the discussion of observations on meteorology made *at sea* in all parts of the globe;" adding that, "as it may possibly happen that observations *on Land* upon an extensive scale may hereafter be made and discussed in the same office, it is desirable that the Royal Society should keep in view and provide for such a contingency."

The subject of a Government system of Meteorological Observations on Land was again brought under the consideration of the Royal Society in a letter from the Board of Trade in May 1865, and the President and

Council were expressly requested to offer suggestions in reference to it. The suggestions which they offered in reply have been made known to the Society, in their leading outlines at least, in my Address of last year, and in No. 82 of our 'Proceedings.' They have been submitted by the Board of Trade to a Committee appointed by itself, whose general approval they are understood to have received; and the whole scheme is now under the consideration of Government in respect to its cost.

The sea-observations, so hopefully spoken of by Captain Maury, were the subject of a very full communication addressed by the President and Council of the Royal Society to the Board of Trade in February 1855, and the recommendations contained therein were made the basis of the instructions given to the Meteorological Office of the Board of Trade at its first formation. The collection of what have since been comprehended under the general designation of "Ocean Statistics" proceeded for some time with much activity and success under the direction of our lamented Fellow the late Admiral FitzRoy. His exertions and those of his assistants were afterwards in great measure diverted to an object which, if it could be—or, to speak more sanguinely, whenever it shall become—practically attainable with a fair measure of scientific certainty, will assuredly both deserve and receive in the highest degree general favour and support. I mean the system popularly known by the appellation of "storm-warnings." Meanwhile, if the recommendations of the Royal Society and the intentions entertained by the Board of Trade shall now receive the hoped-for sanction of the general government, the collection of ocean statistics and their systematic combination will be resumed with fresh vigour, and with all the aids which experience and matured scientific consideration can afford; and at the same time, if our hopes respecting the proposed system of Land-Meteorology are realized, and if its fruits correspond in a fair degree to the expectations which we venture to form respecting them, we shall gradually obtain such a more complete knowledge of the laws which govern the changes of weather in the British Islands and their vicinity, as may enable the predictions of approaching storms or "storm-warnings," if now suspended, to be resumed hereafter, and at no very distant period, with far greater confidence and more assured advantage.

At our last Anniversary I acquainted you that the Legislature of Victoria had voted the sum of £5000 for the construction of a large reflecting telescope to be erected at Melbourne and employed in a thorough survey of the Nebulæ and multiple stars of the southern hemisphere. They also requested the cooperation of the President and Council of the Royal Society in arranging a contract for the work and superintending its execution. We selected for the task one of our Fellows, Mr. Grubb of Dublin, whose well-known optical and mechanical talents gave sure promise of success, and we obtained for him the advantage and assistance of a Superintending Committee, consisting of our late President the Earl of Rosse, Dr. Robinson, and Mr. Warren

De la Rue. The contract for the work was signed on the 19th of January; the progress has been rapid, and I have great pleasure in informing you that, according to all appearance, the instrument will be ready for trial in the spring of 1867. All the large parts of it are ready for mounting, and the rest considerably advanced. The lattice-tube, the appearance of which is known to many of us from the photographs, is put together. It is made of ribs of steel to combine lightness and strength; they are rolled taper to effect this in the highest degree. The equilibrated systems of levers which support the great speculum, with their boxes, are of the same material and are also completed. Three specula have been cast on a plan differing from that of Lord Rosse only by such modifications as were made necessary by their having central apertures. The first speculum came out sound from the annealing furnace, but had two blemishes on its surface which would have required a month to grind out, and Mr. Grubb broke it up without hesitation, though not many years ago such a disk would have been almost inestimable. The second cast has been successfully ground, and its surface is faultless. The third, a duplicate speculum, was cast on the 24th of October. The grinding has been performed by the polishing machine and steam-engine which belong to the telescope, and will accompany it to Melbourne. The trial-piers on which the instrument is to be set up for the examination of the Superintending Committee, are ready.

At the request of the Board of Visitors of the Melbourne Observatory, and at the recommendation of the aforenamed Superintending Committee, I have appointed as Observer with this telescope Mr. Albert Le Sueur, a Graduate at Cambridge and a Wrangler in 1863. He is at present training himself in sidereal astronomy at the Cambridge Observatory under the guidance of Professor Adams, and will be present at the polishing of the specula. Mr. De la Rue has kindly promised to instruct him in the practice of celestial photography; so that there is reason to hope that this magnificent instrument will be used with full intelligence and zeal, and amply repay the munificent spirit that has guided the Legislature of this energetic and prosperous colony.

The large appropriation made by the Colony of Victoria for the construction of this telescope and for its accompanying spectroscope, and for a suitable provision for its effective employment at Melbourne, have not been the only manifestation in the present year of the enlightened spirit which animates and guides the Legislature of that colony. A sum has been remitted and received in this country for the purchase of a complete equipment of self-recording magnetical instruments on the model of those at the Kew Observatory, to be located in the Government Reserve adjacent to the Melbourne Astronomical Observatory, and to be employed under the superintendence of its director, Mr. Ellery. The instruments have been made and verified under the immediate care of the Director of the Kew Observatory, and have been despatched to their destination. The

system of intended observation is modelled on that exemplified at the Kew Observatory.

The intention, adverted to in my last year's Address, of the Government of Mauritius to establish there a magnetic observatory, working with the instruments and adopting the methods exemplified at Kew, has been since matured. The necessary funds have been remitted, and the instruments are made and are now under process of verification at Kew, where Professor Meldrum, the Director of the Mauritius Observatory, is daily expected to arrive, with the view of making himself thoroughly acquainted with the instruments, and with the processes in which they are to be employed. The geographical position of Mauritius is a very important one, both for magnetical and meteorological observations. Hitherto meteorology has been exclusively pursued there, and the researches of Professor Meldrum on the cyclonic storms which prevail in the vicinity of the Island are well known.

Those of our Fellows who remember the assiduity and devotion to scientific pursuits manifested by Mr. Charles Chambers during his employment as one of the assistants of the Kew Observatory, will be glad to learn that he has received from the Government of Bombay the temporary appointment of Superintendent of the Bombay Magnetical and Meteorological Observatory, and in that capacity has been required to submit a scheme for the reorganization of the observatory, with instruments and methods of research suitable to the advance which has been made in these respects in the last twenty-five years. Mr. Chambers's report is understood to be on its way from the Government of Bombay to the India Office, with a view to its being submitted to the consideration of the President and Council of the Royal Society; and should it be approved, it will probably lead to the permanent employment of Mr. Chambers in his present temporary position, and to the thorough utilization of the observations of past years, in addition to the prospect of most efficient work at this observatory, under the best conditions, both personal and material, for the future.

I have to add to the list of magnetic observatories established in the present year one at the Roman Catholic College at Stonyhurst, supplied with the Kew instruments, and pursuing the same methods of observation and reduction. I refer to this with the greater satisfaction, because in addition to the value to science of the actual work performed at the observatory, it may be expected to be, and is expressly designed by the authorities of the College to be a means, amongst others adopted by them, of fostering among the students a taste for scientific pursuits, which may remain with them in after life. For this latter purpose Stonyhurst has added to the more ordinary modes of instruction in natural knowledge that practical instruction which is only to be gained by working under proper tuition in observatories and laboratories directed to special scientific pursuits, among which magnetism, terrestrial and celestial, may now be considered to have taken its place.

It was from the twofold motive of aiding the advancement of science by

this additional observatory on the one hand, and on the other of contributing to the dissemination of a taste for scientific pursuits among a large class of our gentry, that the Council of the Royal Society thought it right to allot last year from the parliamentary grant annually placed at their disposal, a sum sufficient to defray half the cost of a set of magnetical instruments for Stonyhurst.

This is the fortieth year since Mr. Schwabe began at Dessau his series of observations on the Solar spots, which he has continued without intermission from 1826 to the present time. Impressed with the extreme desirableness of continuing beyond the limits of a single life a series already so valuable, the Committee of the Kew Observatory concerted with Mr. Schwabe for the commencement last year at Kew of a series which should run parallel with his for a time, and which afterwards, when the identity or proximate identity of the two should have been established, might, it was hoped, be prolonged indefinitely through future years. Mr. Schwabe's observations and those at Kew have accordingly been proceeding contemporaneously, and the comparison between their results during the ten months from January to October 1866 inclusive, gives reason to believe that the object will be satisfactorily attained. The number of new groups of spots observed at the two stations in the ten months is identical, and *very* similar, if not always quite identical, in each single month; although, as might have been expected from the difference between the continental and insular climates, the number of days of observation at Kew is considerably less than at Dessau.

The results of the first year's experiments with the pendulums which were noticed in my last year's Address as having been supplied to the Indian Trigonometrical Survey, have been received from Colonel Walker, R.A., F.R.S., Superintendent of the Survey. They were made by Captain Basevi at several stations where the triangulation is now proceeding. In a letter to myself accompanying them, dated August 30 of the present year, Colonel Walker says, "Already these experiments are beginning to throw light on the subject of Himalayan attraction; for the observations clearly show that the force of gravity is less than it should be theoretically at the stations in the vicinity of the Himalayas, and that the difference between theory and practice diminishes the further the station is removed from the Himalayas. This seems a remarkable confirmation of the Astronomer Royal's opinion, that the strata of the earth below mountains are less dense than the strata below plains and the bed of the sea. Combining these observations with those which were used by Mr. Baily, including, I believe, all your own, the value of the ellipticity will be $\frac{1}{289}$." The general result obtained from the thirteen stations of my equatorial and arctic voyages (1821–1823) was $\frac{1}{288 \cdot 4}$. That obtained by Mr. Baily from

Captain Foster's experiments in his equatorial and antarctic voyage (1828–1830) was $\frac{1}{289 \cdot 2}$.

In our Transactions of the present year we have an elaborate and valuable memoir by Mr. Abel "On the Manufacture and Compositiou of Gun-cotton," pointing out the causes of the difference in the analytical results obtained by many of the earlier inquirers into its nature, and confirming its composition as determined by Crum and more fully proved by Hadow, and again stated by the Committee of Chemists who reported on Baron von Lenk's Gun-cotton. In pursuing these analytical inquiries, Mr. Abel has tested the methods, both synthetical and analytical, formerly employed, and has devised some modes of analysis of his own. The multiplied and varied experiments which he has made leave no room to doubt the accuracy of his results, though they differ from those of M. Pelouze.

With regard to the processes of manufacture, Mr. Abel has proved by experiments, both in the laboratory and on a manufacturing scale, that Baron von Lenk's method, although it does not at first sight present any important features of novelty, yet unquestionably ensures the attainment of greater uniformity and purity of the product, though Mr. Abel has himself suggested one or two modifications of importance. The most valuable practical result deduced by Mr. Abel from his experiments is, that the instability which has been observed in certain samples of gun-cotton, producing the gradual decomposition of such samples by prolonged keeping, is due to insufficient purification of the material employed, in consequence of which oxidized products of small quantities of resinous and other foreign substances are formed in the manufacture, and are still retained by the tubular fibre of the cotton. These undergo decomposition, and the change extends to the mass. Many of these impurities are removed by the action of the alkaline bath upon the cotton before treating it with the nitric and sulphuric acids, and others may in great measure be dissolved by a final boiling with a weak alkaline solution.

Mr. Abel's paper is an important contribution towards a more complete knowledge than has hitherto obtained of the precautions which are required in the manufacture of gun-cotton in order to diminish still further both the risk of accidents, and the liability to injury of the material when not stored,—as it ought invariably to be when no paramount reason requires an exception,—either under water or in a state of moisture precluding ignition.

Since my Address last year little has been done in regard to the successful application of gun-cotton to the large ordnance employed in the public service. The desideratum for this purpose may be stated to be a form of cartridge, which with the required velocity of the projectile on quitting the piece, shall have produced an approach to an equality of strain upon every point of the bore, from the instant of ignition to that of the discharge. In the absence of a test of the degree to which this is accomplished, experiments on different forms of the cartridge are necessarily tentative, and

the instruction derived from them of comparatively little value. The production of an apparatus by which the actual strain experienced in successive parts of the bore may be recorded, is in fact the first step in a scientific inquiry which should establish the proper relations between the form of the cartridge and the gun. But for the production of an efficient apparatus for this purpose, a chronoscope of greater delicacy and perfection than any we have hitherto possessed in England is indispensable. A chronoscope recently devised by Captain Schultz of the French Artillery appears, as far as can be judged previous to a practical trial, to correspond to these conditions, and to be likely to supply a means of surmounting the difficulty; it is not improbable that it will be tried in the present year.

I proceed to the award of the Medals.

The Copley Medal has been awarded to Professor Julius Plücker, Foreign Member of the Royal Society, for his researches in Analytical Geometry, Magnetism, and Spectral Analysis.

To an audience not exclusively mathematical it is obviously impossible to enter into details of researches which deal with geometrical questions of no ordinary difficulty. Amongst these, however, may be indicated, as especially appreciated by those who are interested in the progress of analytical geometry, his theory of the singularities of plane curves as developed in the "Algebräische Curven," with its six equations connecting them with the order of the curves: the papers on point and line coordinates and on the general use of symbols, may also be noticed as establishing his claim to a position in the department of abstract science which is attained by few even of those who give to it their undivided attention. But Professor Plücker has high merits in two other widely different fields of research, viz. in Magnetism and Spectrology: and to these I may more freely invite your attention.

Shortly after Faraday's discovery of the sensibility of bodies generally to the action of a magnet and of diamagnetism, Professor Plücker, in repeating some of Faraday's experiments, was led to the discovery of magnecrystallic action,—that is, that a crystallized body behaves differently in the magnetic field according to the orientation of certain directions in the crystal. The crystals first examined were optically uniaxal, and it was found that the optic axis was driven into the equatorial position; (that is, of course, assuming that the magnecrystallic action is not masked, in consequence of the external form of the body, by the paramagnetic or diamagnetic character of the substance). New facts, discovered both by Faraday and by Plücker himself, led him to a modification of this law, to the effect that the optic axis was impelled, according to the nature of the crystal, *either* into the equatorial or the axial position. This subject was afterwards followed out by Professor Plücker into the more complicated cases in which the conditions of crystalline symmetry are such as to leave the crystal optically biaxal; and after having recognized the insufficiency of a

first empirical generalization of the law applicable to crystals of the rhombohedral or pyramidal system, and accordingly to uniaxal crystals, he was led to assimilate a crystal to an assemblage of small ellipsoids, capable of magnetic induction, having for their principal planes the planes of crystalline symmetry where such exist; and to apply Poisson's theory. The result of this investigation is contained in an elaborate paper read before the Royal Society in 1857, and published in the Philosophical Transactions for the following year. In this paper Professor Plücker has deduced from theory, and verified by careful experiments, the mathematical laws which regulate the magnecrystallic action. These laws have not necessarily involved in them the somewhat artificial hypothesis respecting the magnetic structure of a crystal from which they were deduced; and at the close of his memoir Professor Plücker recognizes the theory of Professor Sir William Thomson, with which he then first became acquainted, as a sound basis on which they might be established. The laws, however, remain identically the same in whichever way they may be derived.

Another subject to which Professor Plücker has paid much attention is the curious action of powerful magnets on the luminous electric discharge in glass tubes containing highly rarefied gas. In this case the luminous discharge is found to be concentrated along certain curved lines or surfaces. He has succeeded in obtaining the mathematical definition of these curved lines or surfaces, by a simple application of the known laws of electromagnetic action, regarding an element of the discharge as the element of an electric current. With regard to the blue negative light, for instance, starting from a point in the negative electrode, he has shown that there are two totally distinct paths, one or other of which, according to circumstances, it may take, going either within the enclosed space along a line of magnetic force, or else along the surface of the glass in what he calls an "epipolic curve," which is the locus of a point in which the inner surface of the vessel is touched by the line of magnetic force passing through that point.

Ångström appears to have been the first to notice that the spectrum of the electric spark striking between metallic electrodes through air on another gas at ordinary pressures is a compound one, consisting of very bright lines varying with the metal, and others, usually less bright, depending only on the gas. Under the circumstances which presented themselves in his experiments, the latter can frequently be but ill observed; and the diffused light of a rarefied gas in a wide tube is but faint, and does not form very definite spectra. But Plücker found that by employing tubes which were capillary in one part, brilliant light and definite spectra were obtained in the narrow part. These spectra were observed by him with great care, and were found to be characteristic of the several gases and to indicate their chemical nature, though the gases might be present in such minute quantity as utterly to elude chemical research. It further appeared that compound gases of any kind were instantaneously, or almost instantaneously,

decomposed; at least the spectra they offered were the spectra of their constituents.

In a recent memoir, which has only just been published in the Philosophical Transactions, Professor Plücker has investigated the two totally different spectra frequently afforded by the same elementary substance according as it is submitted to the instantaneous discharge of a Leyden jar charged by an induction-coil, or rendered incandescent by the simple discharge of the coil, or else, in some cases, by ordinary flames. The two spectra show a remarkable difference in *character*, and are not merely different in the number and position of the lines which they show. Some phenomena which he had previously noticed receive their explanation by this twofold spectrum.

This difference of spectra is attributed by Professor Plücker, with the greatest probability, to a difference in the temperature of the flowing gas when the two are respectively produced. The discovery opens up a new field of research, the exploration of which may throw much light on the correct interpretation of celestial phenomena, especially in relation to the physical condition of nebular and cometary matter.

Professor Miller,

As we have not the pleasure of the presence of Professor Plücker, I must request you, as our Foreign Secretary, to transmit to him this Medal. He will see in it the strongest evidence of the high estimation in which his labours in various lines of scientific research are held in this country; and I trust you will also express to him the great pleasure which this award gives to his numerous friends here, some of whom have been his fellow-labourers in the same researches.

A Royal Medal has been awarded to Mr. William Huggins for his Researches on the Spectra of some of the Chemical Elements, and on the Spectra of certain of the Heavenly Bodies; and especially for his Researches on the Spectra of the Nebulæ, published in the Philosophical Transactions.

The researches on the stellar spectra referred to in this award were made by Mr. Huggins conjointly with our highly valued Treasurer and senior Vice-President, Dr. William Allen Miller. The position of the latter as one of the officers of the Society and a member of its Council has forbidden the consideration of his claims to share in the honours which the Society can bestow; and in conformity with the spirit of this, our "self-denying ordinance," it would be my duty to dwell altogether on the merits of our Medallist, if, indeed, it were possible in this case to separate between the merits of the two authors of the conjoint research. This is scarcely possible, and I must be excused, therefore, if I sometimes speak of them together.

Fraunhofer, Lamont, and others have at various times attempted to observe the spectra of the planets and fixed stars; yet, though provided with powerful instruments, they obtained no important results.

Mr. Huggins and Dr. Miller devised a method of seeking in the spectra of the fixed stars that evidence of the existence in them of known elementary substances which had been obtained in the case of the sun by Bunsen and Kirchhoff. A preliminary investigation of the spectra of the more important of the terrestrial chemical elements, and their direct comparison with the lines in the spectrum of common air, was undertaken by Mr. Huggins, with the view of providing a standard scale of comparison, which, unlike the solar spectrum, would be always at hand when stellar observations are possible. This was in itself a work of enormous labour; and when completed, the spectra of the fixed stars, including those of some double stars of contrasted colours, were attacked by the two investigators; and by a happy adaptation of comparatively moderate instrumental means, and unwearied diligence in observing and determining by micrometrical measurements the positions of objects that all but elude human vision, their researches have been rewarded by the most complete success.

The spectra of the stars were compared by a method of simultaneous observation with the spectra of many of the terrestrial elements. It is upon this method of *direct comparison* that the trustworthiness of the results obtained chiefly depends, and in this respect these observations stand alone. [In 1815 Fraunhofer recognized several of the solar lines in the spectra of the Moon, Venus, and five of the fixed stars. In 1862 Donati published diagrams of three or four lines in fifteen stars. Recently Secchi, Rutherford, and the Astronomer Royal have given diagrams of the positions, obtained by measurement only, of a few strong lines in several stars.] Eighteen stars have afforded spectra containing lines coinciding with the lines of many of the elementary substances. In thirty-seven more the spectra are full of lines which have not yet been fully compared.

On extending these researches to the Nebulæ, Mr. Huggins made the most unexpected discovery that the spectra of certain of these bodies are *discontinuous,* consisting of bright lines only, whence he drew the conclusion that "in place of an incandescent solid or liquid body transmitting light of all refrangibilities through an atmosphere which intercepts by absorption a certain number of them—such as our sun appears to be—we must probably regard these objects, or at least their photo-surfaces, as enormous masses of luminous gas or vapour. For it is alone from matter in a gaseous state that light consisting of certain definite refrangibilities only, as is the case with the light of these nebulæ, is known to be emitted."

During the last two years Mr. Huggins has examined the spectra of more than sixty nebulæ and clusters. This examination shows that these remarkable bodies may be divided into two great groups: viz. 1st, *true or gaseous* nebulæ, which furnish a discontinuous spectrum, consisting of two

or three bright lines only; and 2nd, what we may distinguish as *spurious nebulæ,* or nebulous matter with clusters, which give a spectrum apparently continuous. Of the latter group a large proportion show signs of resolvability into clusters by telescopes of high power.

In the present year also Mr. Huggins has made a remarkable observation upon the small comet, known as comet No. 1, 1866. He ascertained that the minute nucleus gave a gaseous or discontinuous spectrum; whilst the spectrum of the coma, as though formed by suspended particles which reflected solar light, gave a continuous spectrum.

Since the publication of these results by Mr. Huggins, our investigators have examined with great care the spectrum of the star which is either new or has greatly increased in brilliancy in Corona borealis, and have found that that star has a spectrum of absorption, and also a gaseous spectrum of which hydrogen is probably the source. They have also connected, in one instance at least, the change in a variable star with a variation in its spectrum.

Discoveries like these, which acquaint us not only with the constituents of the heavenly bodies but also with their state of aggregation, are of the nature of those which occur only once in the course of centuries,—like the discovery of the satellites of planets, of solar spots, or of double stars,—and have the strongest possible claim on the Royal Society for such honours as the Society has at its disposal.

Mr. Huggins,

It gives me the greatest pleasure to present you with this Medal: a testimonial of the very high estimation in which your successful labours (conjointly with Dr. Miller) are held by the Society, which has the satisfaction of regarding you as one of its most distinguished Members. You are at an age at which you may reasonably indulge in the prospect of having a long career before you; yet, however long, it will scarcely exhaust the noble field of research which you have opened for yourself, and which is one in which you are quite sure to be accompanied by the sympathy of men of science throughout the world.

A Royal Medal has been awarded to Mr. William Kitchen Parker for his researches in Comparative Osteology, and more especially on the Anatomy of the Skull, as contained in papers published in the Transactions of the Zoological Society and the Philosophical Transactions.

Mr. Parker has for several years past made investigations of great extent and distinguished merit among the *Foraminifera,* the results of which are embodied in Memoirs published by him from 1859 to 1865, in conjunction with Professor Rupert Jones and with Dr. Carpenter in the Annals of Natural History, the publications of the Ray Society, and the Philosophical Transactions.

The award of a Royal Medal to Mr. Parker has been based, however,

not so much on his work in this department of zoology as on his labours in a very different and much more difficult branch of anatomy, Vertebrate Osteology.

In 1860 Mr. Parker published a memoir "On the Osteology of *Balæniceps Rex*," and in 1862 another "On the Osteology of the Gallinaceous Birds and Tinamous," in the Transactions of the Zoological Society; while a third still more important memoir, on the "Skull of the Ostrich Tribe," was read before the the Royal Society in March 1865, and is now published in the Philosophical Transactions. In these elaborate and beautifully illustrated memoirs, Mr. Parker has not only displayed an extraordinary acquaintance with the details of Osteology, but has shown powers of anatomical investigation of a high order, and has made important contributions towards the establishment of the true theory of the vertebrate skull.

MR. WILLIAM KITCHEN PARKER,

I present you with this Medal in testimony of the high esteem in which your investigations are held by those of our body who are qualified to appreciate them, and who look at once with approval and with expectation at the increased and still increasing interest of the communications contributed by you to our Transactions.

The Council have awarded the Rumford Medal to M. Armand Hippolyte Louis Fizeau for his Optical Researches, and especially for his Investigations into the Effect of Heat on the Refractive Power of Transparent Bodies.

In 1849 M. Fizeau rose into celebrity as the experimenter who first succeeded in measuring the velocity of light by observations limited to objects on the surface of the earth. He noted the time required for the passage of light from the place of the observer to a mirror, normal to the path of the light, 8633 metres distant, and back again, by means of a wheel having 720 teeth revolving rapidly. When the wheel made 126 revolutions in 10 seconds, the light that had passed through the notch between two teeth towards the mirror was stopped completely on its return, after reflexion, by the second of the two teeth; showing that the light had travelled 17,266 metres while the wheel had revolved through half the angle subtended at its centre by the distance between the summits of two adjacent teeth, or $\frac{1}{18144}$ second.

In 1859 he wrote a remarkable memoir, "Sur une expérience qui paraît démontrer que le mouvement des corps change la vitesse avec laquelle la lumière se propage dans leur intérieur."

His "Méthode propre à rechercher si l'azimuth de polarisation du rayon refracté est influencé par le mouvement du corps réfringent" (1860) involves such complicated arrangements that great hesitation was felt about accepting the results. But whoever has seen his experiments on the

expansion and the alteration of the refrangibility of bodies when heated, is not disposed to question any conclusions regarded by Fizeau himself as well founded.

In 1862 he published "Recherches sur les modifications que subit la vitesse de la lumière dans le verre et plusieurs autre corps solides sous l'influence de la chaleur,"—the first of a series of memoirs on the change of dimensions and refractive powers of various kinds of glass, and many crystallized substances.

On the 23rd of May, 1864, he read before the Institut "Recherches sur la dilatation et la double refraction du cristal de roche échauffé;" and on the 21st and 28th of May, 1866, "Mémoires sur la dilatation des corps solides par la chaleur."

In these observations he has availed himself of the possibility of forming Newton's rings with the monochromatic sodium light when one of the interfering rays is 52,205 waves in advance of the other, a fact which, conjointly with M. Foucault, he announced in 1849. Using the length of a wave of sodium light (0·0005888 millimetre) as the standard of measure, the position of a ring being observable to within $\frac{1}{10}$ of the distance between two consecutive rings, the variation of the distance between two surfaces producing the Newton's rings can be measured to within $\frac{1}{33967}$ millimetre.

A plate of the substance to be experimented on (let us suppose it to be fluor), usually from 10 to 15 millimetres thick, bounded by parallel plane surfaces, rests upon the platform of a metal tripod (the metal was steel in the earlier observations, platinum with $\frac{1}{10}$ of iridium in the later). The feet of the tripod are screws of equal lengths terminating above in obtuse points. On these points, at a distance of about $\frac{1}{50}$ millimetre above the upper surface of the fluor, rests a plate of glass. By counting the number of rings or bands that pass over a mark on the upper surface of the fluor during a given change of temperature, the corresponding variation of distance between the lower surface of the glass and the upper surface of the fluor is given, and the expansion of the metal being known by a similar process, the expansion of the fluor is found.

The Newton's rings formed between the two surfaces of the fluor depend upon its thickness and its refractive power. The number of rings that pass over the mark on the fluor during a given change of temperature being observed, and its expansion having been found by the preceding observation, the change of its refractive power due to the change of temperature becomes known.

In this way M. Fizeau obtained several very unexpected results. Of these a few may be noticed.

The indices of refraction of most substances were found either to increase or to remain unaltered with an increase of temperature, but in fluor the index of refraction diminishes with an increase of temperature. Diamond, cuprite, and beryl have a maximum density, like water—diamond at

$-42^\circ \cdot 3$ C., cuprite at $-4^\circ \cdot 3$, and beryl at $-4^\circ \cdot 2$. Beryl, when heated, unlike calcite, contracts in the direction of its axis, and expands in a direction making right angles with the axis. Quartz, rutile, cassiterite, spartalite, corundum, and hematite were found to expand in every direction when heated; but in each case the expansion in the direction of the principal axis was different from the expansion in a direction at right angles to the principal axis.

M. Fizeau is also the author of many other important researches—on Moser's images, on photography, on the automatic engraving of photographic images on copper, on the interference of rays of heat, on electricity and the velocity of its propagation, and on the position of the plane of polarization of light reflected from striated metallic surfaces.

Professor Miller,

I have to request you to transmit this Medal to Monsieur Fizeau, in testimony of our interest in his researches and our high respect for his merits, which you have yourself been especially instrumental in placing in a clear light before the Council.

On the motion of Vice-Chancellor Sir W. Page Wood, seconded by Mr. Hogg, it was resolved,—"That the thanks of the Society be returned to the President for his Address, and that he be requested to allow it to be printed."

The Statutes relating to the election of Council and Officers having been read, and Mr. Balfour Stewart and Mr. C. V. Walker having been, with the consent of the Society, nominated Scrutators, the votes of the Fellows present were collected; and the following were declared duly elected as Council and Officers for the ensuing year:—

President.—Lieut.-General Edward Sabine, R.A., D.C.L., LL.D.

Treasurer.—William Allen Miller, M.D., LL.D.

Secretaries.— { William Sharpey, M.D., LL.D.
George Gabriel Stokes, Esq., M.A., D.C.L., LL.D.

Foreign Secretary.—Professor William Hallows Miller, M.A., LL.D.

Other Members of the Council.—Lionel Smith Beale, Esq., M.D.; William Bowman, Esq.; Commander F. J. Owen Evans, R.N.; Edward Frankland, Esq., Ph.D.; John Hall Gladstone, Esq., Ph.D.; William Robert Grove, Esq., M.A., Q.C.; William Huggins, Esq.; Thomas Henry Huxley, Esq., LL.D.; William Lassell, Esq.; Professor Andrew Crombie Ramsay, LL.D.; Colonel William James Smythe, R.A.; William Spottiswoode, Esq., MA.; Thomas Thomson, M.D.; William Tite, Esq.; Vice-Chancellor Sir W. P. Wood, D.C.L.; The Lord Wrottesley, M.A., D.C.L.

The thanks of the Society were voted to the Scrutators.

Receipts and Payments of the Royal Society between December 1, 1865, and November 30, 1866.

Receipts	£	s.	d.
Balances on hand	15	9	0
Annual Subscriptions, Admission Fees, and Compositions	1697	16	0
Rents	253	18	0
Dividends	1541	10	3
Ditto, Trust Funds	283	0	6
Sale of Transactions, Proceedings, &c.	383	0	2
Repayments	96	3	0
Prof. Sylvester, repaid to Donation Fund	25	0	0
	£4295	16	11

Payments	£	s.	d.	£	s.	d.
Balance due to Bankers				135	7	10
Salaries, Wages, and Pension				1031	12	0
The Scientific Catalogue				178	17	6
Books for the Library and Binding				335	16	6
Printing Transactions and Proceedings, Paper, Binding, Engraving, and Lithography				1334	14	8
General Expenses (as per Table subjoined)				483	9	2
Donation Fund	80	0	0			
Wintringham Fund	35	5	0			
Copley Medal Fund	4	15	0	129	17	9
J. Clerk Maxwell, Bakerian Lecture	4	0	0			
Rev. Dr. Stebbing, Fairchild Lecture	2	18	9			
Croonian Lecture (Poor of St. James's Parish)	2	19	0			
				3629	15	5
Balance at Bank				638	8	1
Balance of Catalogue Account				18	19	9
,, Petty Cash Account				8	13	8
				£4295	16	11

WILLIAM ALLEN MILLER,
Treasurer.

Estates and Property of the Royal Society, including Trust Funds.

Estate at Mablethorpe, Lincolnshire (55 A. 2 R. 2 P.), £126 0*s*. 0*d*. per annum.
Estate at Acton, Middlesex (34 A. 3 R. 11 P.), £110 0*s*. 0*d*. per annum.
Fee farm near Lewes, Sussex, rent £19 4*s*. per annum.
One-fifth of the clear rent of an estate at Lambeth Hill, from the College of Physicians, £3 per annum.
£14,000 Reduced 3 per Cent. Annuities.
£28,969 15*s*. 7*d*. Consolidated Bank Annuities.
£513 9*s*. 8*d*. New $2\frac{1}{2}$ per Cent. Stock—Bakerian and Copley Medal Fund.

Scientific Relief Fund.

Investments up to July 1865, New 3 per Cent. Annuities £6052 17 8

£6052 17 8

Dr.	£	s.	d.	*Cr.*	£	s.	d.
Balance	181	10	8	By Grants	160	0	0
Subscriptions	13	13	0	Balance	213	14	10
Dividends	178	11	2				
	£373	14	10		£373	14	10

Statement of Income and Expenditure (apart from Trust Funds) during the Year ending November 30, 1866.

Income	£	s.	d.		£	s.	d.
Annual Subscriptions					1111	16	0
Admission Fees					170	0	0
Compositions					416	0	0
Rents					253	18	0
Dividends on Stock (exclusive of Trust Funds)					997	3	10
,, on Stevenson Bequest					544	6	5
Sale of Transactions, Proceedings, &c.					383	0	2
Chemical Society, for Proceedings, 1865–66					50	0	0
Chemical Society, Tea Expenses	£16	7	8	}	32	15	4
Linnean Society, Tea Expenses	16	7	8	}			
Geographical Society, Gas at Evening Meetings	8	4	8	}	13	7	8
Cambridge Local Examination Committee, Gas	4	8	0	}			
St. George's Rifles—Gas		15	0	}			
					3972	7	5
Income available for the Year ending Nov. 30, 1866					3972	7	5
Expenditure in the Year ending Nov. 30, 1866					3364	9	10
Excess of Income over Expenditure in the Year ending Nov. 30, 1866					£607	17	7

Expenditure	£	s.	d.		£	s.	d.
Salaries, Wages, and Pension					1031	12	0
The Scientific Catalogue					178	17	6
Books for the Library					197	5	0
Binding ditto					138	11	6
Printing Transactions, Part II. 1865, and Part I. 1866	350	18	9	}	1334	14	8
Ditto Proceedings, Nos. 78–86	276	14	9	}			
Ditto Miscellaneous	76	6	0	}			
Paper for Transactions and Proceedings	228	16	5	}			
Binding and Stitching ditto	78	2	5	}			
Engraving and Lithography	323	16	4	}			
Upholstery, Cleaning, and Repairs					48	8	8
Miscellaneous Expenses					39	9	0
Coal, Lighting, and Gas-fittings					136	6	9
Tea Expenses					49	2	1
Fire Insurance					28	11	6
Donation:—Mablethorpe Schools					2	2	0
Taxes					8	19	2
Law Expenses					126	7	10
Advertising					9	15	6
Postage, Parcels, and Petty Charges					34	6	8
					£3364	9	10

WILLIAM ALLEN MILLER,

Treasurer.

The following Table shows the progress and present state of the Society with respect to the number of Fellows:—

	Patron and Royal.	Foreign.	Having compounded.	Paying £2 12s. annually.	Paying £4 annually.	Total.
November 30, 1865.	6	47	309	3	274	639
Since elected	......	+3	+6	......	+9	+18
Since readmitted ..	......	......	......	......	+1	+1
Since compounded..	......	......	+1	......	−1	
Since deceased	−1	−1	−14	......	−15	−31
Since defaulter	......	......	......	......	−1	−1
November 30, 1866.	5	49	302	3	267	626